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Final Report

SURVEY REPORT FOR THE RHODE ISLAND REGION SIDE-SCAN SONAR AND BATHYMETRIC SURVEY

RHODE ISLAND REGION LONG-TERM DREDGED MATERIAL DISPOSAL SITE EVALUATION PROJECT

FINAL

Survey Report for the Rhode Island Region Side-Scan Sonar and Bathymetric Survey

SAIC Project No. 01-0440-04-5746-400
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Rhode Island Region
Long-Term Dredged Material Disposal Site Evaluation Project

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LIST OF ACRONYMS

CTD	Conductivity-Temperature-Depth
DGPS	Differential Global Positioning System
EPA	Environmental Protection Agency
MLLW	Mean Lower Low Water
MTL	Mean Tide Level
NOAA	National Oceanic and Atmospheric Administration
NAE	New England District
OLLD	Ocean and Lake Levels Division
SMMP	Site Management and Monitoring Plan
TIN	Triangulated Irregular Network
TVG	Time Varied Gain
USACE	U.S. Army Corps of Engineers

ACKNOWLEDGMENTS

This report presents the results of a combined bathymetric and side-scan sonar survey conducted over two areas in Rhode Island Sound being evaluated as potential dredged material disposal sites. Science Applications International Corporation (SAIC) of Newport, RI conducted the fieldwork from 16 July 2003 through 30 July 2003 as a subcontractor to Battelle who was under contract with the U.S. Army Corps of Engineers (USACE), New England District (NAE). All fieldwork was conducted aboard the *R/V Beavertail*, owned and operated by P&M Marine Services of Jamestown, RI. Steve Moreau was the vessel captain and John Lawless was the deckhand during all of the survey operations. The *Beavertail* was based out of its homeport at Fort Getty in Jamestown, RI for the duration of the survey operations.

John Morris, Natasha Pinckard, Karen Hart, Kate Montgomery, Pam Luey, and Tom Waddington of SAIC were responsible for the survey operations aboard the *Beavertail*.

1.0 INTRODUCTION

1.1 Background

Over the last two decades, a number of studies have confirmed the need for a regional dredged material disposal site. In the 1980’s two separate needs studies were performed, one of which was for the Commonwealth of Massachusetts and the other for the State of Rhode Island. In addition, a Rhode Island Governor directed task force study (1993) and Rhode Island commission study (1996) also investigated the need for a regional dredged material disposal site. In response to recent requests of Governor Almond and Senator Reed, EPA and the Corps is currently evaluating the feasibility of designation of a long-term disposal site in the Rhode Island Region under Section 102(c) of the MPRSA in a forthcoming EIS. The EIS will evaluate other possible alternatives including open water disposal sites, other disposal and management options, and the no action alternative. It must be emphasized here that designation of a site does not by itself authorize or result in disposal of any particular material. It only serves to make the designated site a disposal option available for consideration in the alternatives analysis for each individual dredging project in the area. Each future project must assess whether it meets the ocean disposal criteria for discharge at such a site and demonstrate the need for ocean disposal.

The EPA has the responsibility of designating sites under Section 102(c) of the Act and 40 CFR 228.4 of its regulation. Because of its experience with the Providence River project, the Corps will administer the technical studies and public participation process of the EIS with EPA oversight. The EIS will support the EPA's final decision on whether one or more dredged material disposal sites will be designated under the MPRSA. The EIS will include analysis applying the five general and 11 specific site selection criteria for designating ocean disposal sites presented in 40 CFR Parts 228.5 and 228.6, respectively.
The survey described in this report is the first of a series of surveys to be completed in the summer of 2003 to help fully characterize two areas in Rhode Island Sound (Areas E and W) in which alternative disposal sites to be evaluated as future dredged material disposal sites in the EIS will be identified (Figure 1-1). This survey provided the initial broad-scale physical seafloor characterization data that will be used:

- to plan subsequent summer 2003 field sampling activities;
- to identify potential cultural resources;
- to assist with future sediment transport analysis and interpretation studies; and
- to assist with future numerical modeling.

1.2 Survey Objectives

The objectives of the survey effort described herein included the acquisition of side-scan sonar and single-beam bathymetric data necessary to provide an initial broad-scale physical characterization of the seafloor over two areas (Areas E and W) in Rhode Island Sound. The primary intent of this initial characterization was to differentiate areas of varying sediment composition, to identify potential cultural resources, and to develop accurate bathymetric maps of the area. Based on an initial review of the side-scan sonar imagery data, selected sediment grab samples were acquired (as time permitted) over both areas to confirm (or ground-truth) the seafloor composition interpretation of the side-scan sonar acoustic data.

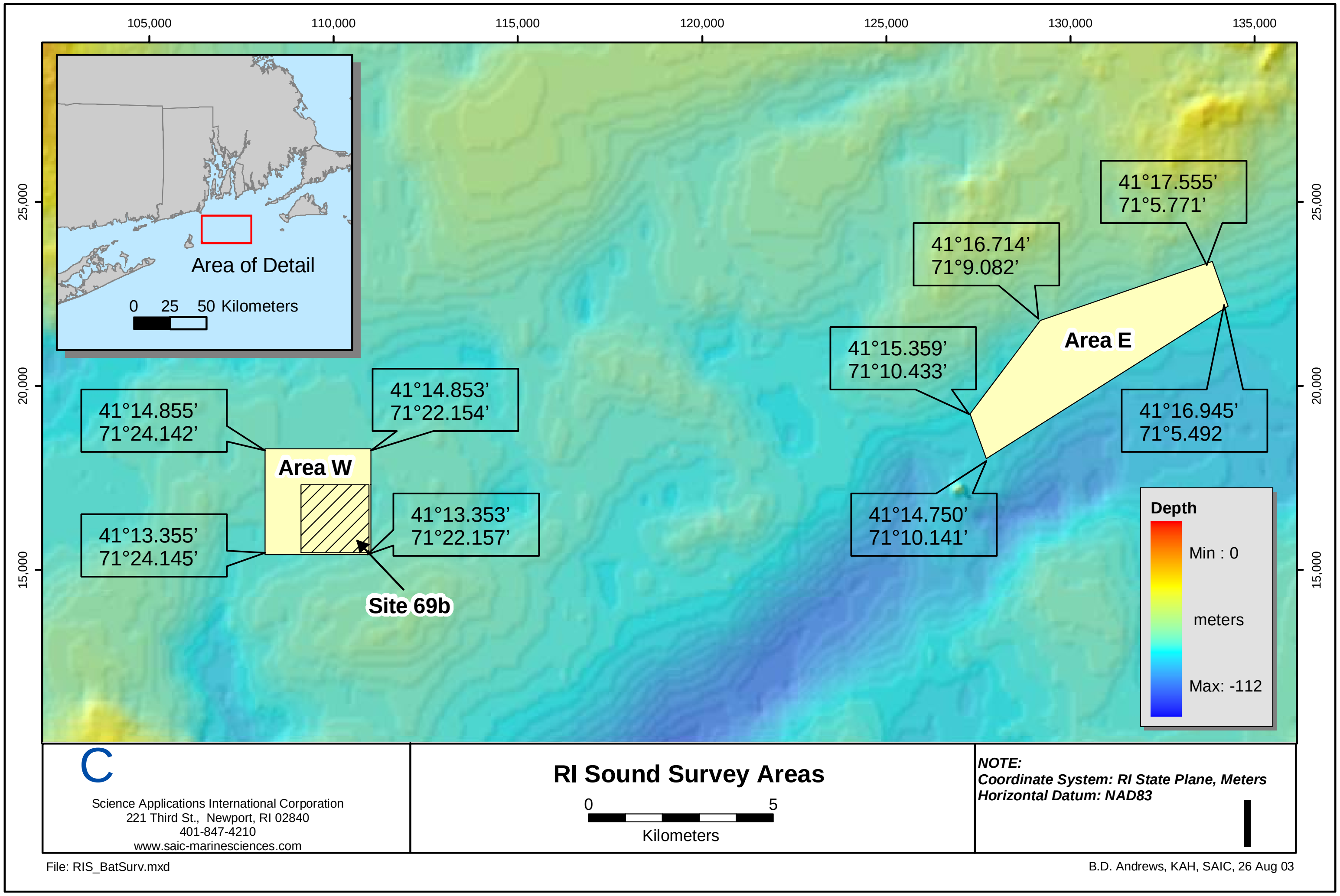

Figure 1-1. Location of the Survey Areas E and W in Rhode Island Sound.

2.0 METHODS

A detailed description of the field data acquisition and processing techniques for each of the main survey data acquisition systems is presented in the sections below. All operations were conducted aboard the *R/V Beavertail*, which was based out of its homeport in Jamestown, Rhode Island, for the duration of the survey from 16 July 2003 through 30 July 2003 (Table 2-1). With the exception of an initial CPU problem with the leased side-scan sonar topside data acquisition system and a period of large southerly swell during the middle portions of the survey effort, the survey operations were not affected by any significant weather or equipment-related downtime. A few of the survey days were shortened due to increasing winds and building southerly seas in the late afternoon.

2.1 Navigation and Survey Control

During field operations, a Trimble DSM212L Differential Global Positioning System (DGPS) receiver provided precise navigation data. Because of its proximity to the survey area, the U.S. Coast Guard differential beacon broadcasting from Montauk, NY was used for generating the real-time differential corrections. During all survey operations, the DGPS system output real-time navigation data (NAD83 Latitude and Longitude) at a rate of once per second to an accuracy of ±3m. Prior to departure from the dock on each field survey day, the proper operation of the navigation system was confirmed by comparing the output DGPS position with the known precise position of a survey point on the dock.

Coastal Oceanographic's HYPACKMax® survey and data acquisition software was used to provide the real-time interface, display, and logging of the vessel position and depth sounding data. Prior to field operations, HYPACKMax® was used to define a State Plane grid (Rhode Island State Plane Coordinates) around the survey area and to establish the planned bathymetric and side-scan survey lines. During the survey operations, the incoming navigation data were translated into state plane coordinates, time-tagged, and stored within HYPACKMax®. Depending on the type of field operations being conducted, the real-time navigation information was displayed in a variety of user-defined modes within HYPACKMax®.

2.2 Bathymetric Survey

2.2.1 Bathymetric Data Acquisition

Single-beam, bathymetric data, meeting the USACE Class I survey standards (USACE 2002), were acquired over both survey areas concurrently with the side-scan sonar data acquisition. Depth soundings were acquired along 13 mainscheme survey lanes spaced at 180m intervals and oriented along a northeast-southwest direction over Area E in eastern Rhode Island Sound (Figure 2-1). Depth soundings were also acquired along 17 mainscheme survey lanes spaced at 180m intervals and oriented along an east-west direction over Area W in western Rhode Island Sound (Figure 2-2). In addition, a series of cross-lanes were also established perpendicular to the main survey lines to provide the crosscheck comparison data needed to evaluate the consistency of the bathymetric data. Some additional survey lanes were also run during the last days of the survey to fill-in any gaps in the side-scan sonar data; most of these gaps were caused either by the necessity to maneuver the boat away from fishing gear or by the occasional loss of navigation data.

Table 2-1. Summary of Bathymetric, Side-Scan Sonar, and Grab Sampling Operations Aboard the R/V *Beavertail* at Areas E and W in Rhode Island Sound.

Date	Day Type	Comments
7/13 thru 7/15	Mobilization	Mob survey gear on *Beavertail* alongside in Jamestown, RI / resolve side-scan sonar processor problem
7/16/2003	Survey	Begin side-scan sonar and single-beam survey in Area E / seas to 6-ft in the afternoon with SW 20-25 kt
7/17/2003	Survey	Complete 100% side-scan sonar and single-beam survey in Area E / snag gear twice, lose one set of fins
7/18/2003	Survey	Begin side-scan sonar / single-beam survey in Area W
7/19/2003	Survey	Complete initial 100% side-scan sonar / single-beam survey in Area W / holiday due to 69b buoy
7/20/2003	Survey	Conduct detailed single-beam survey in Site 69b (separate project)
7/21 thru 7/28	Wx / Standby	Standing-by for better weather / processing initial 100% side-scan sonar data
7/29/2003	Survey	Conduct side-scan sonar pick-ups in Area E and grab-sampling over selected locations
7/30/2003	Survey	Conduct side-scan sonar pick-ups in Area W, grab-sampling over selected locations, and Site 69b bathy
7/31/2003	Demobilization	Demob survey gear from *Beavertail* alongside in Jamestown, RI

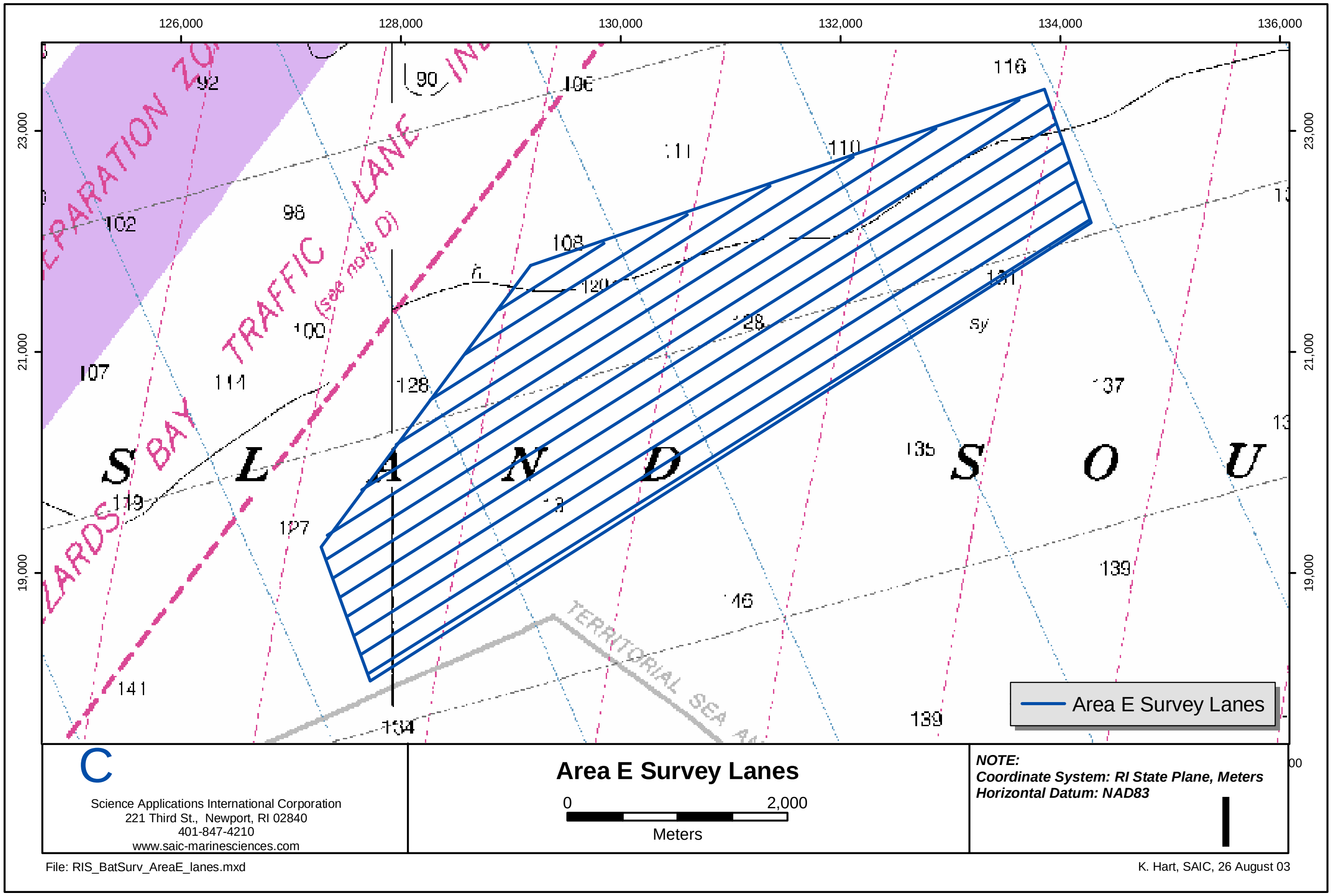

Figure 2-1. Planned Survey Lanes over Area E During the Summer 2003 Single-beam Bathymetry and Side-scan Sonar Survey.

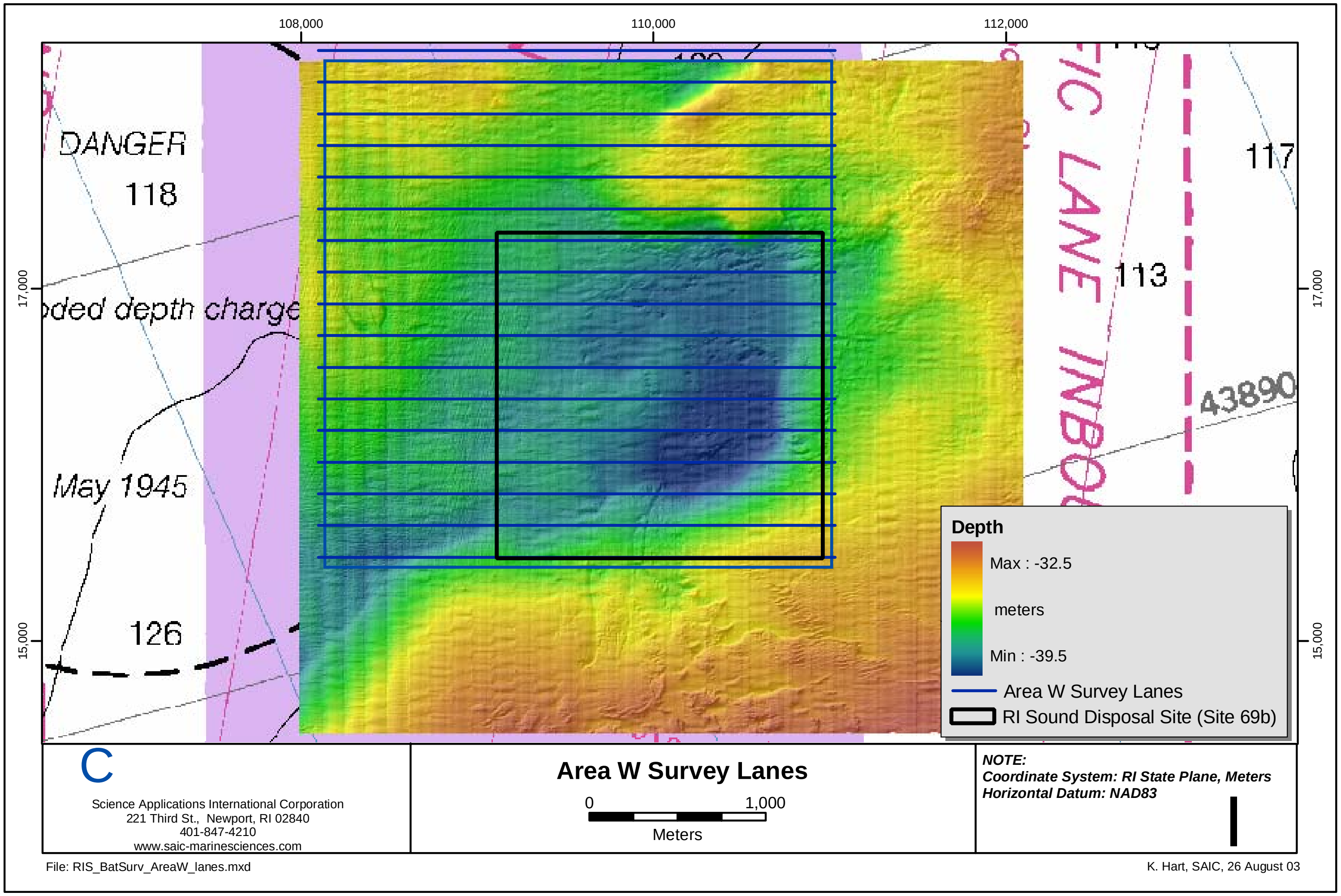

Figure 2-2. Planned Survey Lanes over Area W During the Summer 2003 Single-beam Bathymetry and Side-scan Sonar Survey.

During the bathymetric survey operations, the HYPACKMax® survey software was interfaced with an Odom Hydrotrac® survey echosounder, as well as the Trimble DGPS. The Hydrotrac® used a narrow-beam (3°), 208-kHz transducer, produced a continuous analog record of the bottom, and transmitted approximately 5 digital depth values per second to HYPACKMax®. Within HYPACKMax®, the time-tagged position and depth data were merged to create depth records along the actual survey track. These records were viewed in real-time to ensure adequate coverage of the survey area.

The echosounder transducer was attached to an over-the-side mount deployed along the starboard side of the *Beavertail.* The horizontal distance between the transducer and DGPS antenna was measured and the offset applied in HYPACKMax® during data acquisition. Though the vessel draft changed slightly during the course of the survey operations due to changes in vessel loading (primarily fuel), the transducer draft was maintained at one meter throughout the survey by routinely monitoring the height of the pole prior to departure from the dock. The one-meter draft correction was applied directly to the raw echosounder data within the Hydrotrac® topside recorder and no further draft corrections were applied by HYPACKMax®. Based on settlement and squat tests conducted aboard the *Beavertail* prior to the survey operations, the dynamic draft impacts at standard survey speeds (generally below six knots) were negligible.

A Seabird Electronics SBE-19® conductivity-temperature-depth (CTD) profiler was used to calculate vertical profiles of the water column density and from that the sound velocity profiles at the beginning and end of each survey day. These casts were taken in the deeper waters of each survey area to account for the sound velocity over the full range of depths encountered during the survey.

2.2.2 Bathymetric Data Processing

The bathymetric data were fully edited and processed using the HYPACKMax® single-beam data processing modules. Raw position and sounding data were edited as necessary to remove or correct questionable data, sound velocity and draft corrections were applied, and the sounding data was reduced to Mean Lower Low Water (MLLW). The details are described below.

Sound Velocity Corrections
During bathymetric survey data acquisition, an assumed and constant water column sound velocity of 1500 m/sec was entered into the Odom echosounder. In order to account for the variable speed of sound through the water column, CTD profile data were used to calculate vertical profiles of the water column sound velocity at the beginning and end of each survey day. Each CTD cast was processed to produce a one-meter bin-averaged sound velocity profile from the sea surface down to the depth of the cast. The digital CTD cast data were grouped by day and stored within a master spreadsheet file for additional analysis and eventual export into HYPACKMax®.

After the daily sound velocity processing and analysis was completed, the data were used to generate a daily sound velocity profile table within HYPACKMax®. This average sound velocity table was based on a composite of each of the casts obtained on a particular day and extended well beyond the deepest depth encountered on the survey. Based on the assumed sound velocity entered into the echosounder during data acquisition and the observed sound velocity reflected in the daily sound velocity profile table, HYPACKMax® computed and applied the required sound velocity corrections to all of the sounding records.

Tidal (or Water-Level) Corrections
Observed water level data from the NOAA primary tide station at Newport, RI were obtained through NOAA's Ocean and Lake Levels Division's (OLLD) National Water Level Observation Network (http://www.co-ops.nos.noaa.gov/). The six-minute Newport tide data were periodically downloaded

from the OLLD web site and the appropriate range and phase offsets were applied to transfer this data out to the Rhode Island Sound survey areas. Based on conventions established during prior surveys in this area, a zero phase offset and a 0.85 ratio offset were applied to the observed Newport tidal height data. The corrected Newport water level data was then used to create daily tidal corrector files within HYPACKMax® that were then used to reduce all of the sounding data to the MLLW vertical datum.

Cross-Check Comparisons
After the bathymetric data were fully edited and reduced to MLLW, cross-check comparisons on overlapping data were performed in order to verify the proper application of the correctors and to evaluate the overall consistency of the entire data set. Because of the survey pattern used for acquiring the bathymetric survey data, a reasonable number of cross-check comparison points were created at the intersections between survey lines oriented perpendicular to each other. Using the HYPACKMax® Statistics routine it was possible to systematically compute the differences between all points from different survey lines that fell within a user-specified distance of each other. For these datasets, the cross-check comparisons were based on a search radius of 10 m. The results of this cross-check analysis are presented in Section 3.

Data Reduction
After the data were verified through the cross-check comparisons, they were then run through the HYPACKMax® Mapper routine in order to reduce the size of the full data set in a systematic way. By using an averaging algorithm, the routine also helps to filter out the impacts of the sea action that was prevalent during most of the survey operations. Because of the rapid rate at which a survey echosounder can generate data (approximately five depths per second during this survey), the along-track data density for a single-beam survey tends to be very high (multiple soundings per meter). In most cases, these data sets contain many redundant data points that can be eliminated without any effect on the overall quality of the data. The Mapper routine examines the full data set along each survey line and averages all data points that fall within a user-specified grid cell to produce a single average value for each cell. The output from this routine is a merged, ASCII-xyz file that may contain anywhere from 2 to 10% of the original data set. These greatly reduced, but still representative, data sets are far more efficient to use in the subsequent modeling and analysis routines. For this survey, the data were mapped to an interval of both 5 and 10 m for use in all subsequent analyses.

2.2.3 Bathymetric Data Analysis and Presentation

The primary intent of this analysis was to evaluate the seafloor surface defined by the bathymetric data in an attempt to characterize the topography and to identify any unique seafloor features. Because single-beam bathymetric survey data typically covers only a small percentage of the total seafloor area (approximately 5%), these analysis tools rely on a large degree of interpolation between the discrete survey data points in order to generate a three-dimensional seafloor surface model. This interpolation usually works well in flat or gently-sloping areas, but in steep and irregular areas the interpolation of the surface can be very dependent upon the orientation of the survey lines and the density of the data around the area.

The reduced 10 m averaged trackline data was imported to ArcGIS 8.2 for gridding to a continuous raster image surface. The Spatial Analyst extension for ArcGIS was used to explore the variance of the bathymetric trackline data and determine the optimal gridding parameters. Several gridding routines were investigated before final interpolation using Kriging; the Kriging method produced a variance grid along with the calculated surface. This variance grid provided a good indication of how well the chosen Kriging parameters calculated the surface. Using the optimal Kriging parameters, the resulting gridded dataset was used for all subsequent analysis and graphics production.

2.3 Side-Scan Sonar Survey

2.3.1 Field Methods

The side-scan sonar data were acquired with an Edgetech DF-1000® digital side-scan sonar system operating at dual frequencies of 100 and 384 kHz. The lower frequency data were used for providing wide area coverage, and the higher frequency data were used for providing higher-resolution images of particular features of interest. The side-scan sonar fish was towed behind the survey vessel by an armored signal cable that provided power to the towfish and two-way communication with the topside Triton-Elics ISIS® data acquisition system. Typically between 80-100m of cable was deployed to maintain the towfish at the proper altitude above the seafloor. The layback between the navigation system and the towfish was computed based on the amount of cable deployed and the depth of the towfish; this layback value was applied during the data processing phase. The topside data acquisition system recorded acoustic data from the towfish and position information from the navigation system, and displayed real-time side-scan sonar imagery on a PC monitor. The side-scan sonar range scale was set to the 100-m setting to provide the initial 100% imagery coverage over the required areas.

Side-scan sonar systems provide an acoustic image of the seafloor by detecting the strength of the backscatter returns from signals emitted from a towed side-scan sonar transducer array. The side-scan transducers operate similar to a conventional depth-sounding transducer except that the towfish has a pair of opposing transducers aimed perpendicular to and directed on either side of the vessel track. Side-scan sonar data can reveal general seafloor characteristics and also provide the size and location of distinct objects. Dense objects (e.g., metal, rocks, hard sand seafloor areas) will reflect strong signals and appear as dark areas in the records presented in this report. Conversely, areas characterized by soft features (e.g., silt or mud sediments), which absorb sonar energy, appear as light areas in the sample records.

2.3.2 Side-Scan Sonar Data Processing and Analysis

During data acquisition, each survey line was saved into a separate file to facilitate post-processing. During post-processing, each line was individually reviewed using Chesapeake Technologies SonarWeb® image processing software. Within SonarWeb®, towfish layback (calculated using the recorded cable out distance and towfish depth) was applied to the navigation data, water column and time varied gain (TVG) adjustments were made to the acoustic data, and then the data were merged together using the SonarWeb® mosaic utility. After the mosaic was completed, it was saved and exported as a geo-referenced TIFF (Tagged Image File Format) file. These TIFF files were then used for a variety of subsequent analysis techniques. Ultimately, fully geo-referenced TIFF image mosaics were created for both survey areas and individual high-resolution screen grabs were created for particular features of interest. Based on the imagery mosaics, geographic positions for areas of differing seafloor composition were delineated and defined to help focus the subsequent sediment grab sampling operations.

2.4 Sediment Grab Sampling

Based on a preliminary interpretation of the acoustic imagery data in both survey areas, several potential grab sample locations were established over areas of differing acoustic return. As time permitted during the final two days of survey operations, sediment grab samples were collected over a representative subset of the planned stations using a Van-Veen type grab sampler (surface area 0.5 m^2). Especially over many coarser-grained seafloor areas, multiple grabs were obtained at one site if the grab did not close properly (i.e. large pebbles or cobbles may have become caught between the jaws of the clam-shell type bucket and would not allow the bucket to seal). After each successful grab sampling operation, the contents of the top of the grab were photographed and a physical description was annotated in the field logbook; samples were not retained for any additional grain size or other lab analyses. Eventually the navigation data recorded during each of the successful grab sampling operations were merged with the physical description information in a comprehensive table summarizing the results of the grab sampling operations (Table 2-2).

Table 2-2. Summary of Supplemental Sediment Grab Samples Obtained over Areas E and W in Rhode Island Sound .

AREA E GRABS

Target	Date	Easting	Northing	Latitude	Longitude	Good_NoGood	Description
ln24_2	7/29/2003	132343.19	21093.43	41.27262009	-71.11398386	G	olive, sandy silt, moist to wet, soft
ln18_1	7/29/2003	131677.72	21491.54	41.27623106	-71.12190539	NG	no penetration, empty grab
ln18_1b	7/29/2003	131679.01	21515.25	41.27644449	-71.12188877	G	till, gravel, rocks
ln12_1	7/29/2003	131860.99	22129.56	41.28196862	-71.11968464	NG	no penetration, empty grab
ln12_1b	7/29/2003	131881.41	22147.66	41.28213079	-71.11943995	G	till, gravel, cobble
ln08_2	7/29/2003	130500.55	21819.33	41.27922779	-71.13593902	G	brown medium to coarse sand with shell fragments and pebbles, worms
ln00_1	7/29/2003	129494.26	21839.28	41.27944478	-71.14794913	G	till, brown coarse sand and gravel, numerous mussel shells, pebbles
ln08_3	7/29/2003	129743.92	21217.68	41.27383869	-71.1449995	NG	grab did not close
ln08_3b	7/29/2003	129772.03	21229.14	41.27394084	-71.14466345	G	olive brown fine sand, small crab, many worms, quahog, bivalve shells, wet, firm
ln24_3	7/29/2003	130390.23	20381.39	41.26628462	-71.13732746	NG	grab did not close
ln24_3b	7/29/2003	130421.03	20402.36	41.26647227	-71.13695886	G	brown fine sand, firm, amphipod tube mat, amphipods, tubes
ln18_2	7/29/2003	129812.79	20344.26	41.26597179	-71.14422023	G	brown coarse firm sand with rocks, gravel, shells, till, quahog, amphipods
ln26_1	7/29/2003	128877.73	18881.68	41.25283649	-71.15544807	G	reddish brown uniform coarse sand, firm, tubes, amphipods
ln20_2	7/29/2003	128209.17	18958.91	41.25355547	-71.16342123	NG	grab did not close
ln20_2b	7/29/2003	128227.16	18973.66	41.25368766	-71.1632059	G	brown silty sand with shells, tubes, crabs, small pebbles, wet
ln14_1	7/29/2003	128992.6	20222.23	41.26490285	-71.15401384	G	gravel, rocks, shells
ln14_1b	7/29/2003	129040.99	20237.18	41.26503573	-71.15343567	NG	grab did not close
ln14_1c	7/29/2003	129069.42	20256.03	41.26520443	-71.15309551	G	brown firm, uniform, medium sand, amphipod and worm tubes
ln06_1	7/29/2003	128931.62	20942.3	41.27138862	-71.15470738	G	brown silty sand with shell fragments, tubes, amphipod tubes, soft and wet

AREA W GRABS

Target	Date	Easting	Northing	Latitude	Longitude	Good_NoGood	Description
West_04	7/30/2003	109175.73	17571.76	41.24150508	-71.39053947	G	olive silty sand, amphipod tubes, worms, bivalves
West_03	7/30/2003	108504.81	16690.65	41.23357863	-71.39855537	G	olive silty sand, dense amphipod tubes, worms, soft
West_02	7/30/2003	108330.83	18179.16	41.24698343	-71.40061028	G	olive sand with rocks, till, shells, crabs, pebbles
West_01	7/30/2003	110088.41	17983.32	41.24520002	-71.37964501	G	rocks, till, shell fragments

3.0 RESULTS

Over the six days of fieldwork spread across a two-week timeframe all required survey data was acquired. Initially, two days were spent in each area to acquire the side-scan sonar imagery data that provided at least 100% coverage of the seafloor; during these operations, concurrent single-beam bathymetric data was acquired as well. After the initial side-scan sonar and bathymetric data were processed and analyzed, an additional field day was spent in each area to fill-in any side-scan sonar coverage gaps and to collect sediment grab samples over areas of differing acoustic return. This section provides an overview of the overall data quality and coverage and then presents the combined results as a broad-scale physical characterization of each of the survey areas.

3.1 Survey Coverage and Data Quality

The entire sea floor of both Area E and Area W, as well as some contiguous areas outside of the area boundaries, were imaged. Some initial coverage gaps were evident in the imagery data, primarily due to the presence of fishing gear or vessels along one of the planned survey lanes. All of the coverage gaps identified after the initial data acquisition effort were adequately covered during the final two days of fieldwork. Because of the large number of distinct seafloor features evident in both survey areas, it was a reasonably straightforward process to verify the consistency of the towfish positioning and the accuracy of the resulting side-scan sonar mosaics. The numerous seafloor features that could be identified on overlapping lanes provided many opportunities to verify the proper computation and application of the towfish layback. Other features, such as the numerous disposal trails evident in the Area W mosaic, extended across many lanes and provided a good indication of the strong lane-to-lane consistency of the side-scan sonar imagery data.

For the bathymetric data, despite at least 1 meter of sea action during most of the data acquisition and the long distances between the primary tide station and the survey areas, the bathymetric cross-check results showed generally consistent agreement between the overlapping data points. In Area E, the HYPACKMax® Statistics routine identified 40 points that overlapped within 10 m of each other between the mainscheme lanes and the cross lanes. The computed mean difference for these comparison points was 0.19 m with a standard deviation of 0.46 m. The distribution of the differences about the mean was very consistent, with a similar number of points evenly distributed on both sides of the mean difference.

In Area W, the HYPACKMax® Statistics routine identified 756 points that overlapped within 10 m of each other between the mainscheme lanes and the cross lanes. There was a much larger number of overlap points in this area, because a separate single-beam survey conducted in the same time-frame over Site 69b provided about 75 cross-check comparison lanes that were spaced at a 25-m interval. The computed mean difference for these comparison points was -0.03 m with a standard deviation of 0.26 m. Again, the distribution of the differences about the mean was very consistent, with a similar number of points evenly distributed on both sides of the mean difference. The cross-check results for both areas confirm the consistency and accuracy of the bathymetric data.

3.2 Physical Characterization of the Sites

A combination of the side-scan sonar, bathymetric, and grab sample results were used to generate an overall physical characterization of these sites. The side-scan sonar image mosaic provided the most comprehensive overview of each of the areas. The relatively widely spaced bathymetric data provided an accurate indication of the general bottom topography in each area. The sediment grab samples helped to confirm and refine the side-scan sonar interpretation of the seafloor sediment composition.

Because the seafloor within both of these areas was comprised of a range of bottom materials, the side-scan sonar imagery data provided a relative indication of the bottom type. In these mosaics, darker areas represented stronger acoustic returns (higher reflectance) and indicated glacially-derived harder seafloor surface materials such as well-consolidated sand, gravel, till, and boulders. Within Area W they also indicated recently deposited dredged material, which was made up of a mixture of primarily coarse-grained materials. The lighter areas of the mosaic represented weaker acoustic returns (lower reflectance) and indicated somewhat softer or finer-grained seafloor surface material such as unconsolidated fine sand or silty sand. Although some resolution was lost when creating small-scale mosaics over large areas, they provided a useful overview and enabled a broad seafloor characterization of each survey area.

In general, seafloor sediments in Rhode Island Sound and Block Island Sound have been largely derived from unconsolidated subaerial and subaqueous glacial and postglacial deposits (McMaster and Luscher 1960). Glacial deposits that could be found in Rhode Island Sound include glacial drift deposits or till, glacial moraine deposits, and somewhat finer-grained glaciolacustrine deposits (Needell and Lewis, 1984). Sediment available for deposition can be composed of some fine and very fine sand, silt, and clay, but the quantities are generally small and usually found in deeper and depositional seafloor areas (McMaster and Luscher 1960). As discussed below, the results from this survey were consistent with the expected glacial origins of the seafloor deposits in both survey areas.

3.2.1 Physical Characterization of Area E

The gridded model depth view of Area E showed a gradually sloping bottom towards the south from a bathymetric ridge along the northern boundary of the survey area (Figure 3-1). The minimum depth observed during the survey over this area was 33.5 m MLLW and occurred on the northern ridge. The maximum depth of 42.7 m MLLW occurred in the southern portion of the area.

The full area mosaic of Area E and a more detailed review of the higher resolution raw data showed that the area was made up of highly varying sediment types (Figure 3-2). The northeastern section of the area had a very hard acoustic return and was comprised of coarse sand, gravel, and till. Large boulders could be seen throughout this area and are indicated in some of the higher-resolution enlargements (Figure 3-2). Grab samples collected in this region were generally very coarse and contained gravel, coarse sand, and till (Figure 3-3, Table 2-2). Near the southern area, the sediment became softer and was composed of sand and silty sand. Sand waves were observed in this region as well (Figure 3-2). Grab samples collected in this region were softer and wetter and composed of fine sand and sandy silt (Figure 3-3; Table 2-2).

The northwestern portion of Area E had varying sediment types. There were areas of very coarse sand and gravel with a hard acoustic return adjacent to softer sediment types with lower reflectance (Figure 3-2). Two adjacent grab samples (ln14_1 and ln14_1c) taken in close proximity to each other had differing sediment types (till and gravel and medium sand, respectively) (Figure 3-3; Table 2-2).

Other than scattered small-scale features identified as lobster gear, no obvious cultural or man-made artifacts were detected within the imagery data in Area E. Particularly in the northeastern portions of the survey area where strong reflectors dominated the imagery data, the ability to clearly identify potential man-made artifacts from among the numerous natural artifacts was limited.

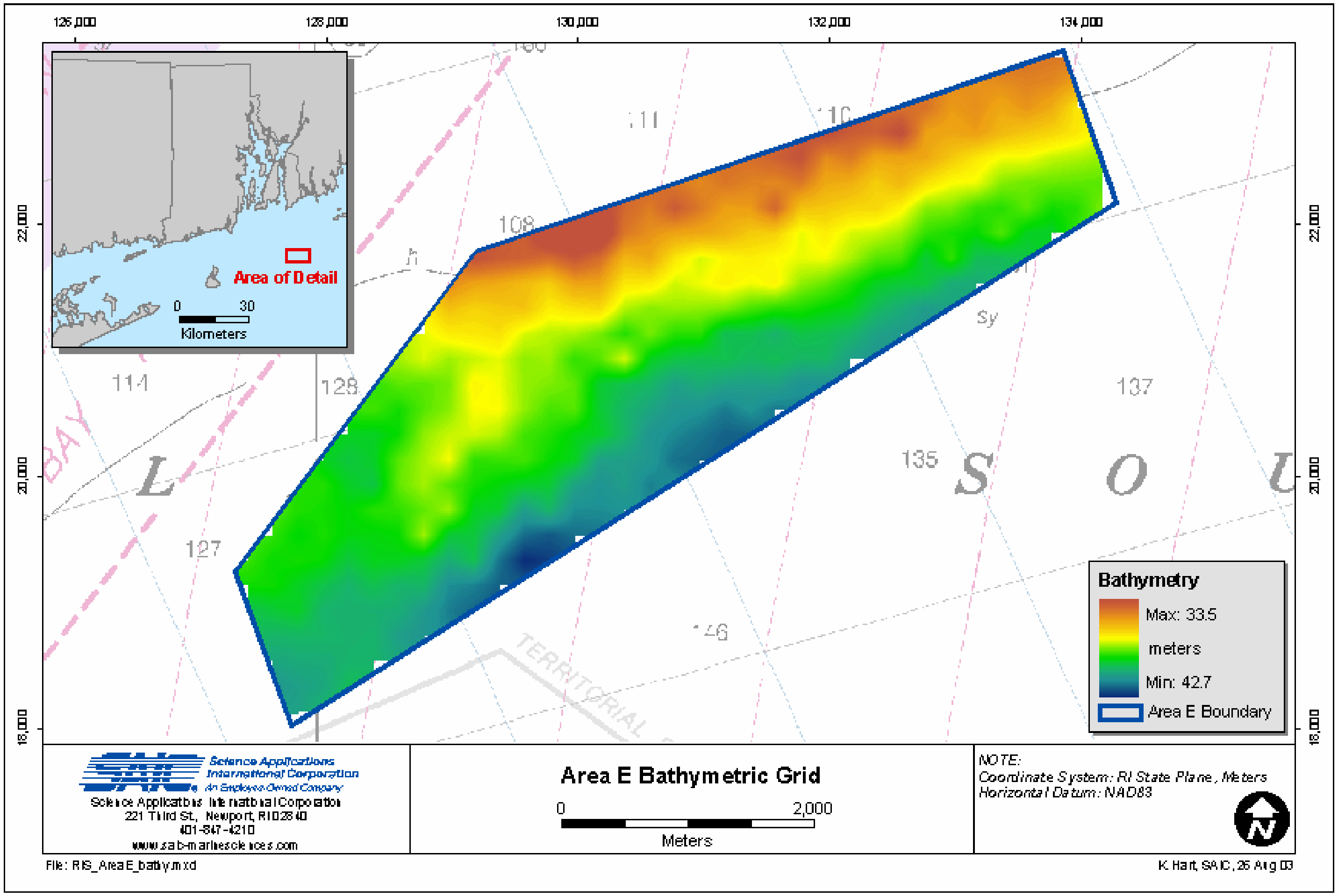

Figure 3-1. Bathymetric Survey Grid over Area E Derived from Single-beam Bathymetry Acquired During Side-scan Sonar Survey Operations in July 2003.

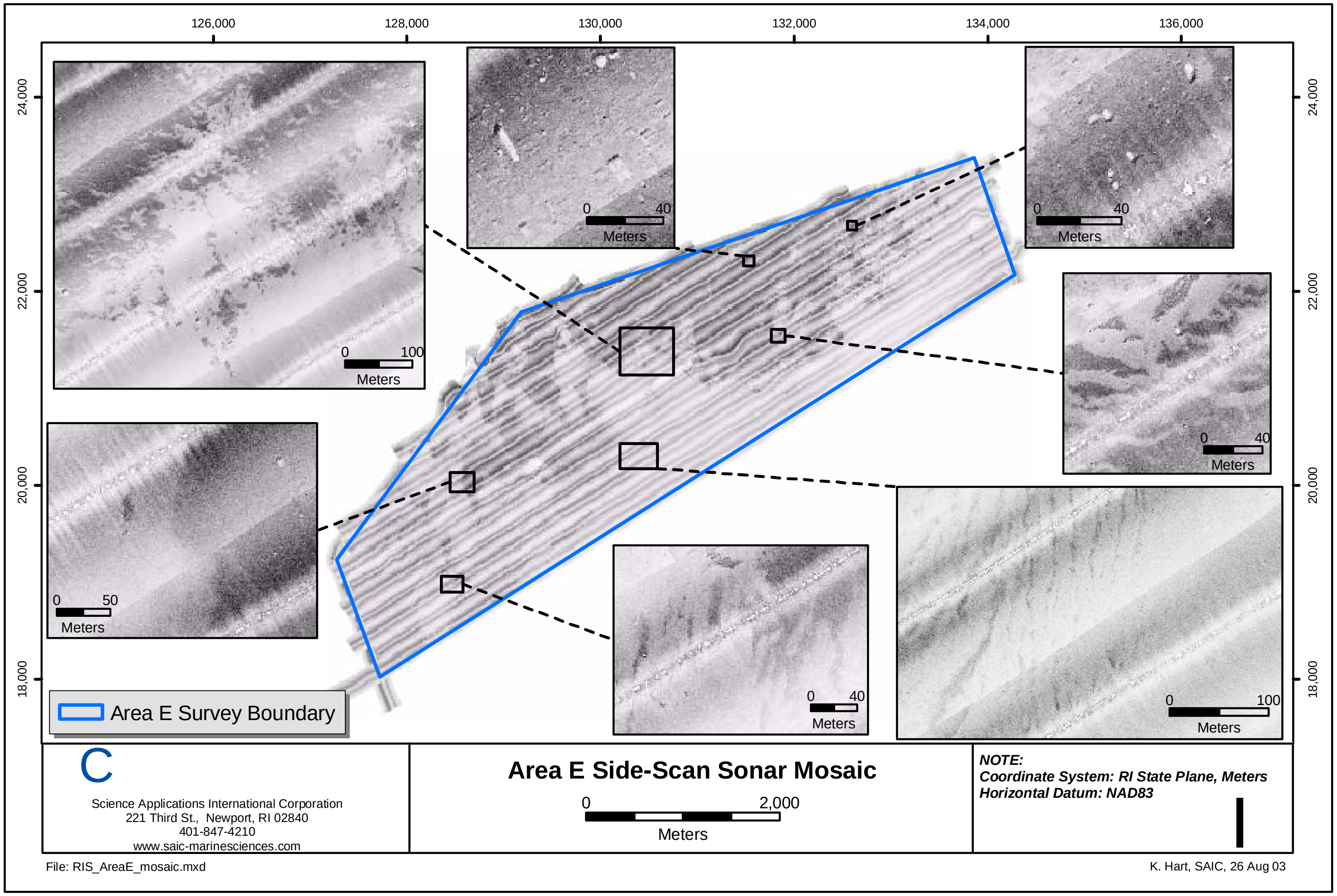

Figure 3-2. Acoustic Imagery Mosaic (with Zoomed-in Views of Selected Areas) of Area E Developed from 100 kHz Side-scan Sonar Data Acquired in July 2003.

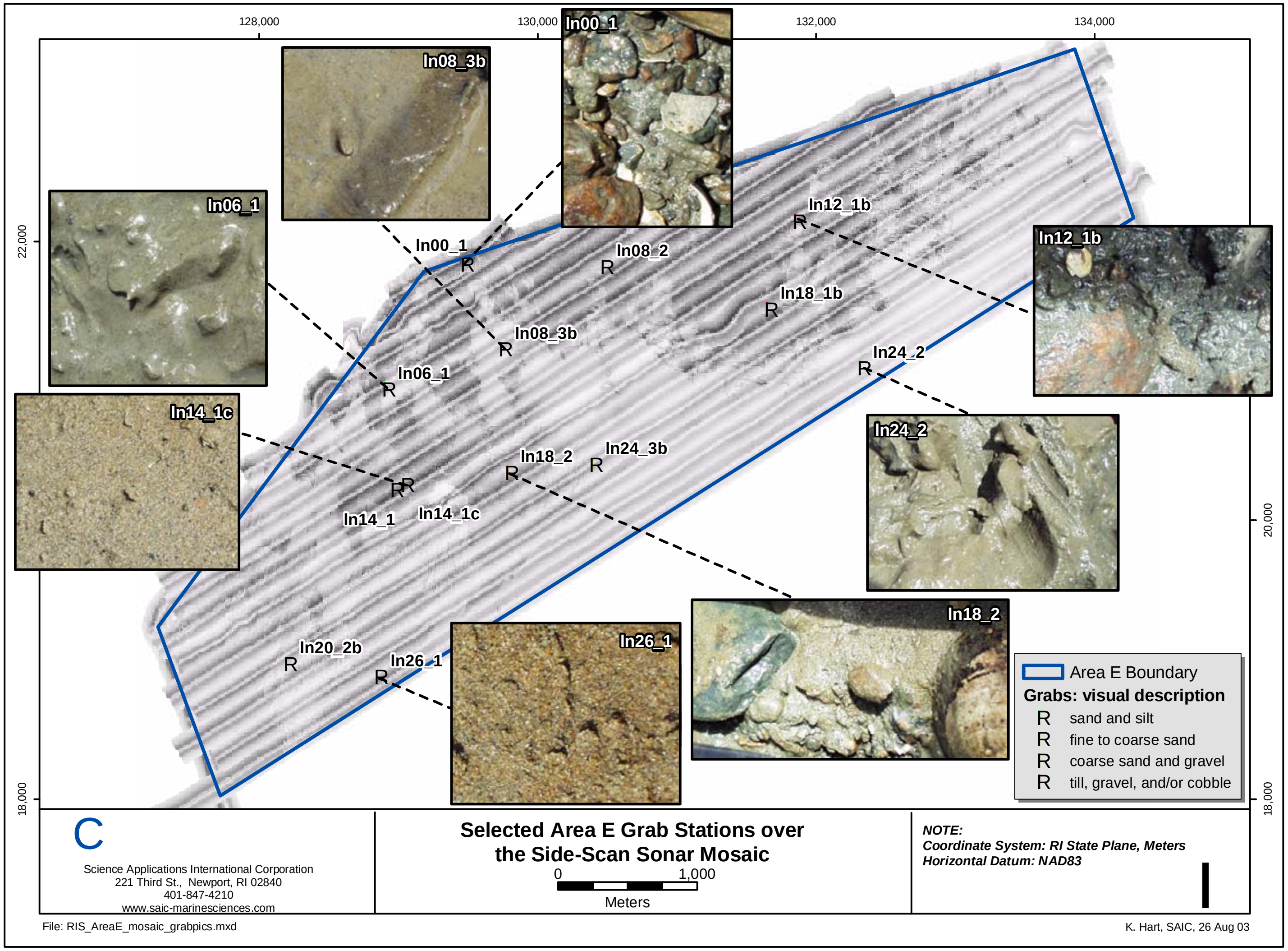

Figure 3-3. Photos from Selected Grab Sample Stations Shown over the Acoustic Imagery Mosaic of Area E.

Within Area E, the side-scan and bathymetry overlay model view showed that the bathymetric ridge in the northern region corresponded well with the harder acoustic returns associated with the gravel, till, and coarse sand areas identified in the side-scan sonar mosaic (Figure 3-4). In general, most of the shallower water depths in Area E corresponded well with coarser-grained, glacially-derived sediment observed in the side-scan sonar mosaic. Similarly, the deeper areas corresponded well with the lower-reflectance, softer sediment identified in the side-scan sonar mosaic.

3.2.2 Physical Characterization of Area W

Both multibeam bathymetry, collected in February 2003 (prior to disposal operations at Site 69b) covering the entire Area W survey area, and higher-resolution single-beam bathymetry, collected in July 2003 over Site 69b, were used to supplement the single-beam bathymetry acquired during this effort. This supplemental data helped to improve the overall resolution of the bathymetric model in this area. The gridded and hillshaded model depth view of Area W showed that Site 69b was located in a general bathymetric depression (Figure 3-5) that was bordered by a slight ridge to the north and east. In the southeastern corner of Area W was another bathymetric ridge. Small disposal mounds were observed in the western portion of Site 69b and reflected recent disposal activity associated with the on-going Providence River dredging project. The minimum depth observed during the survey over Area W was 34.5 m MLLW and occurred on the northeastern ridge. The maximum depth was 39.5 m MLLW and occurred in a trough in the southeastern area of Site 69b.

The full area mosaic of Area W and a more detailed review of the higher resolution raw data showed that the area was also made up of varying sediment types ranging from glacially-derived sediment to dredged material (Figure 3-6). Site 69b was dominated by lower-reflectance acoustic returns, but dredged material disposal operations were evident over the entire site (Figure 3-6). Several disposal mounds were observed in the western portion of the site, with numerous barge disposal trails leading away from this current area of disposal; these disposal trails are low relief features associated with small amounts of material falling from the barge as it departs from the main disposal point. Lesser dredged material disposal activity was also evident along the paths of the disposal trails in the eastern region of Site 69b (Figure 3-6).

Outside of Site 69b, Area W was largely made up of coarse-grained glacial sediment to the north and softer sediment to southwest (Figure 3-6). Grab samples in the northern region of Area W were made up of gravel, till, and coarse sand, while just south of this region, the grab samples were composed of softer and wetter sediment (sand and silt) (Figure 3-7; Table 2-2). Trawl scar marks were also evident in the softer seafloor areas just to the south of the coarser-grained northern region (Figure 3-6). Other than numerous disposal-related features (e.g., mounds and disposal trails) and trawl scars, no obvious cultural or man-made artifacts were detected within the imagery data in Area W.

The major bathymetric and side-scan sonar features in Area W included dredged material deposits and ridges of glacially-derived sediment (Figure 3-8). Within Site 69b, the small disposal mounds noted in the bathymetry clearly corresponded with the dredged material identified in the side-scan mosaic (Figure 3-8). The trough that can be seen in the bathymetry in the south and eastern region of Site 69b overlaid on an area of lower-reflectance in the side-scan mosaic. Outside of Site 69b, the side-scan and bathymetry overlay model view clearly showed that the bathymetric ridge in the northern region corresponded to the high-reflectance, coarse-grained glacial sediment on the side-scan mosaic (Figure 3-8). In the southwest, the sediment was softer and in deeper water.

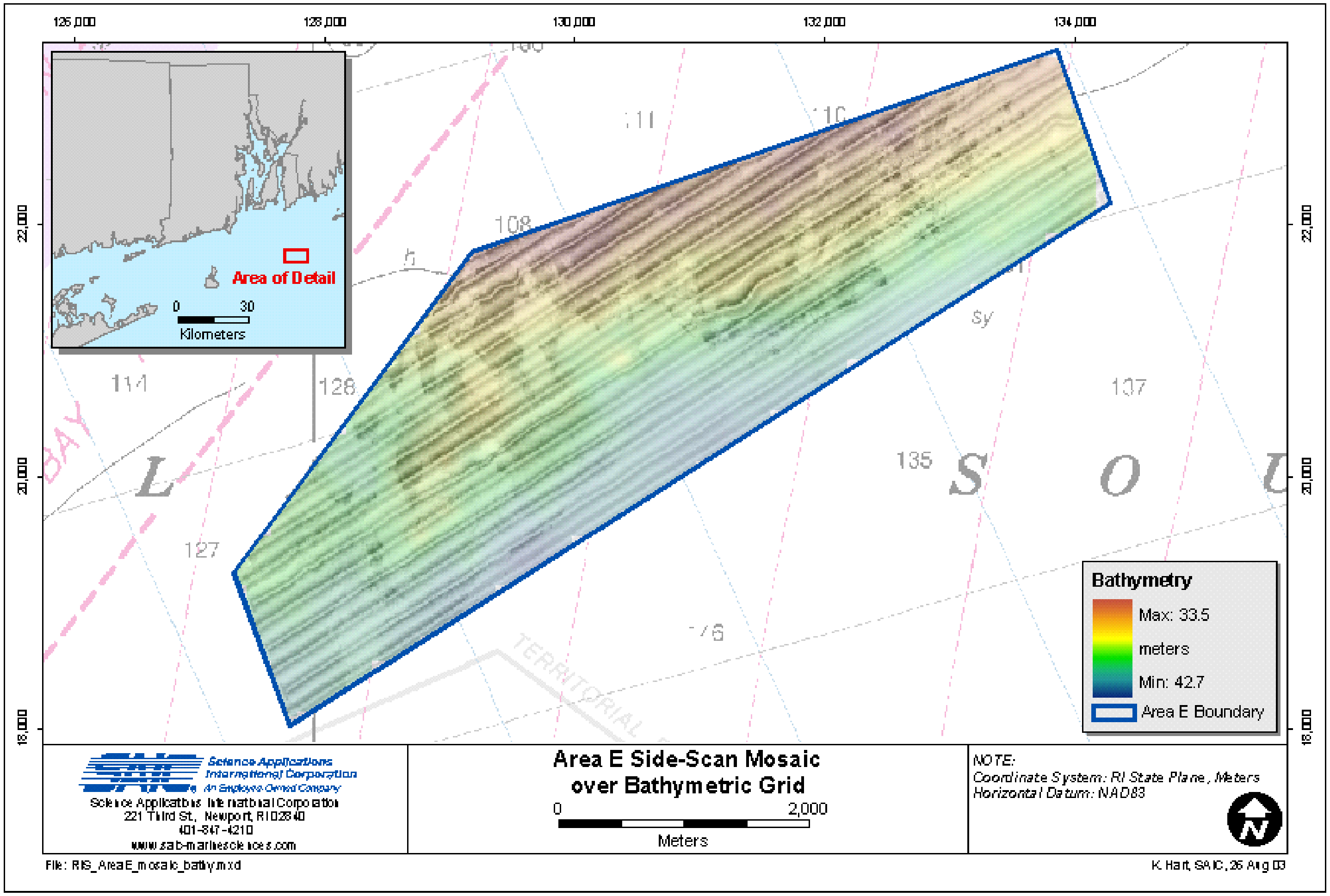

Figure 3-4. Color-coded Bathymetric Grid Shown over the Imagery Mosaic for Area E.

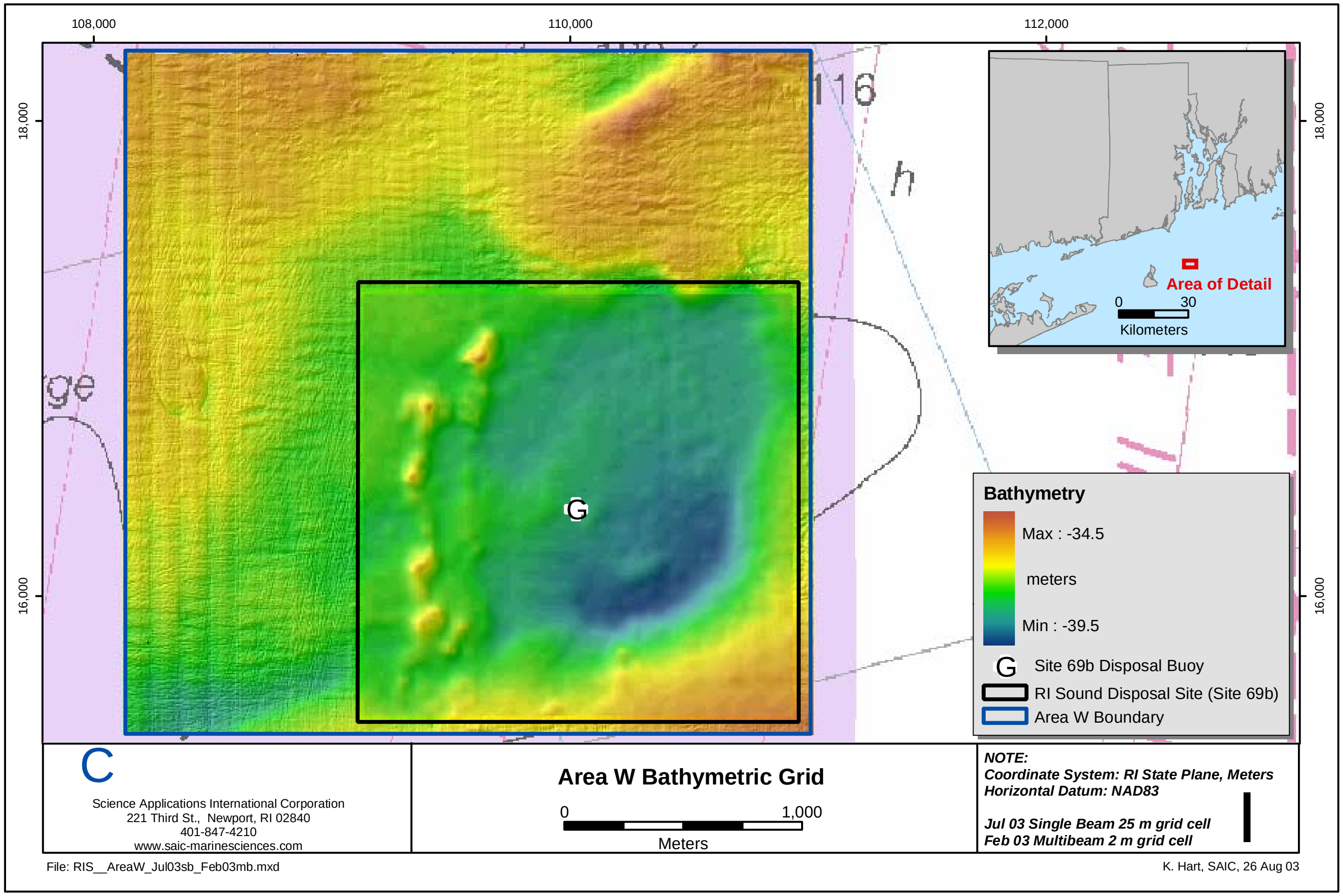

Figure 3-5. Bathymetric Survey Grid over Area W Derived from Single-beam Bathymetry Acquired over Site 69b in July 2003 and Multibeam Bathymetry Acquired over the Area W in February 2003.

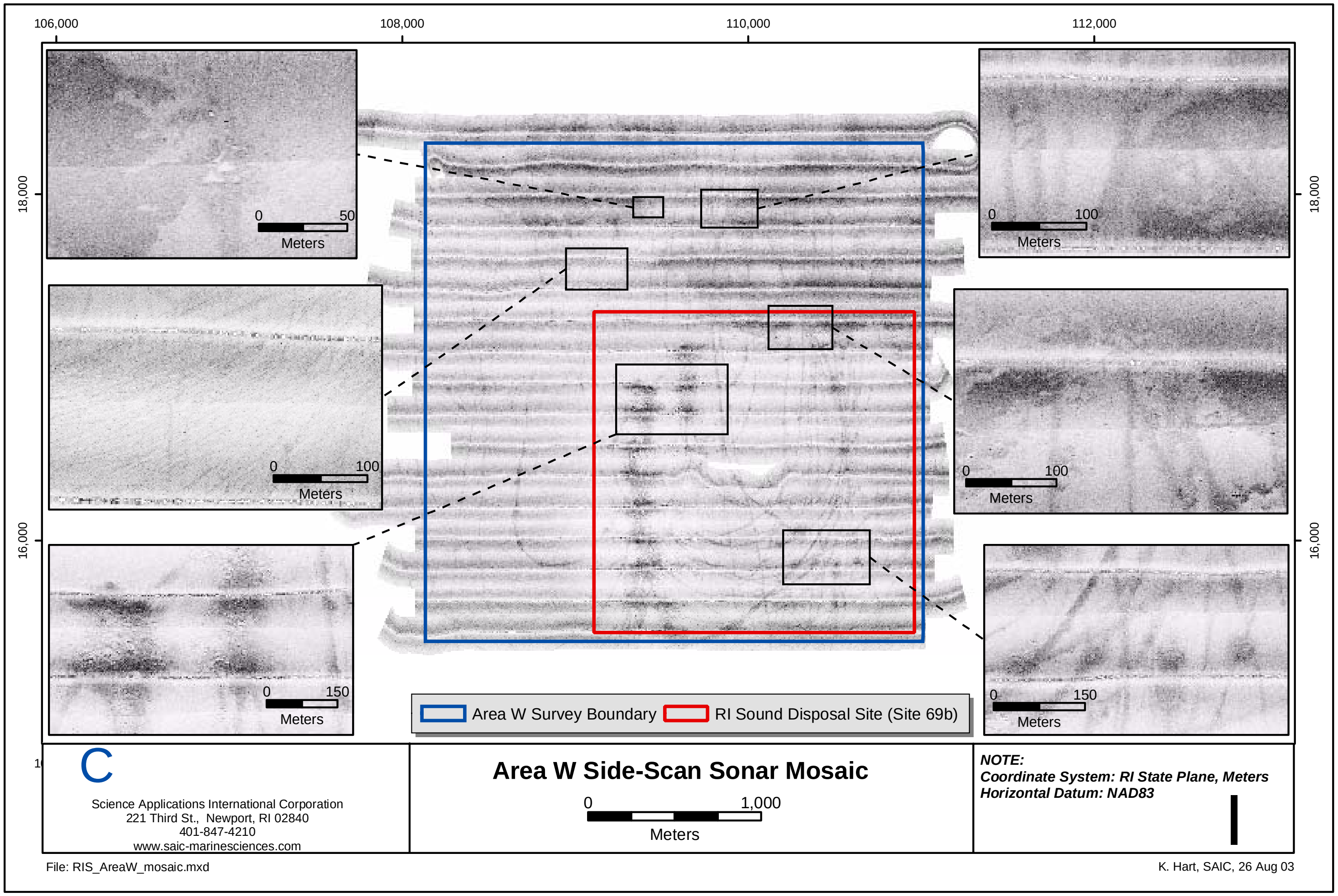

Figure 3-6. Acoustic Imagery Mosaic (with Zoomed-in Views of Selected Areas) of Area W Developed from 100 kHz Side-scan Sonar Data Acquired in July 2003.

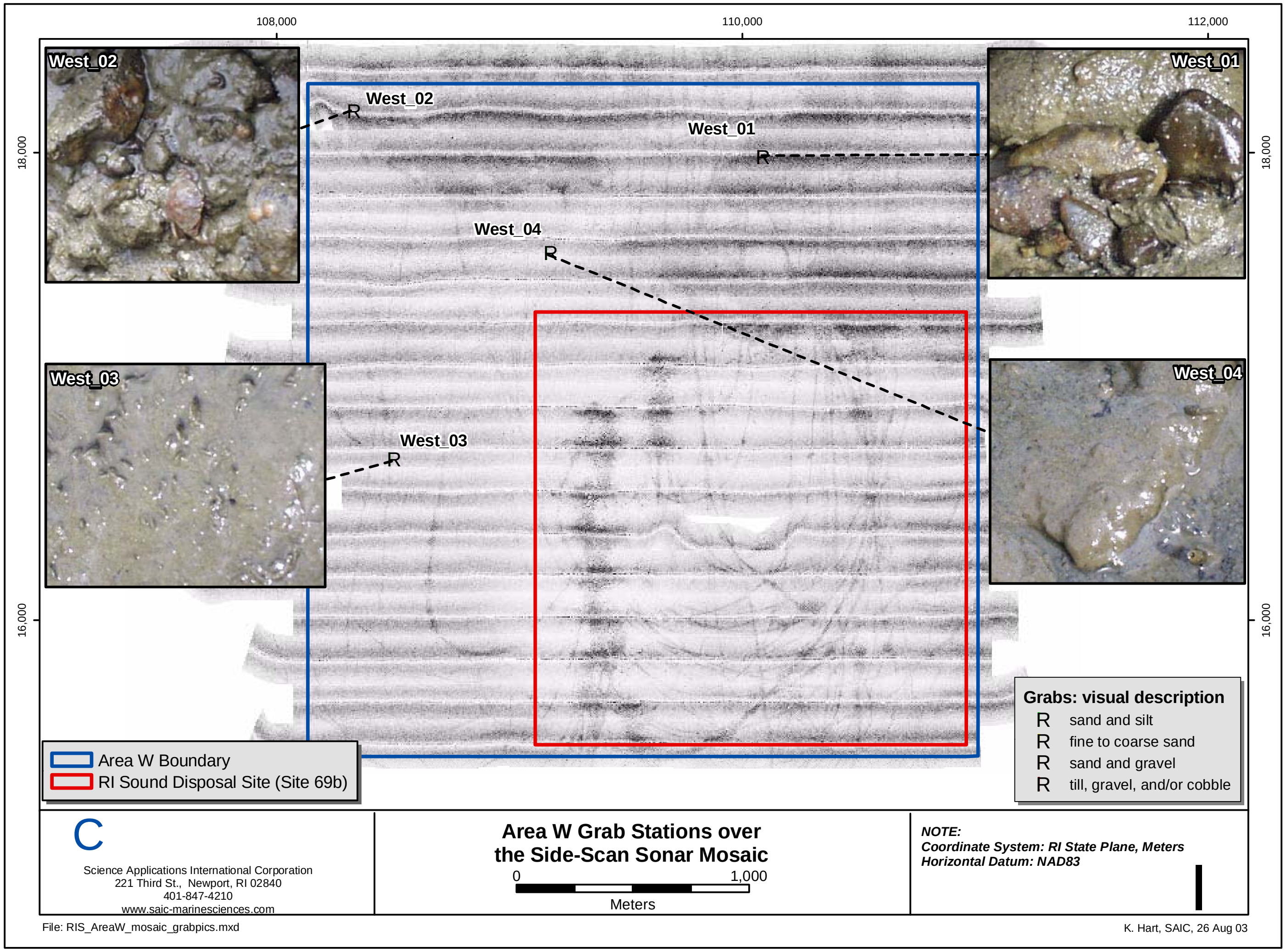

Figure 3-7. Photos from Selected Grab Sample Stations Shown over the Acoustic Imagery Mosaic of Area W.

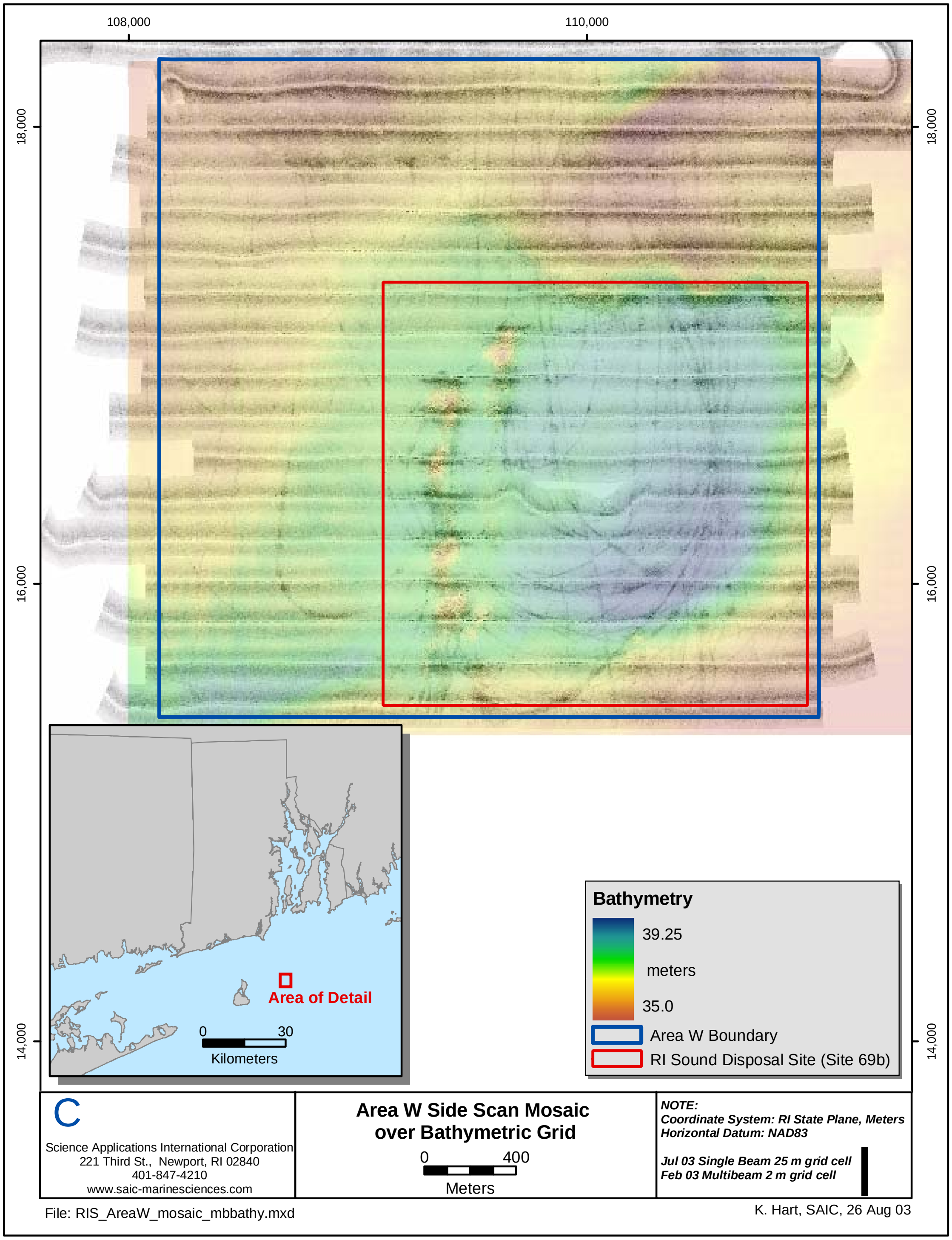

Figure 3-8. Color-coded Bathymetric Grid Shown over the Imagery Mosaic for Area W.

4.0 REFERENCES

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